Tsunamis

Chapter 4

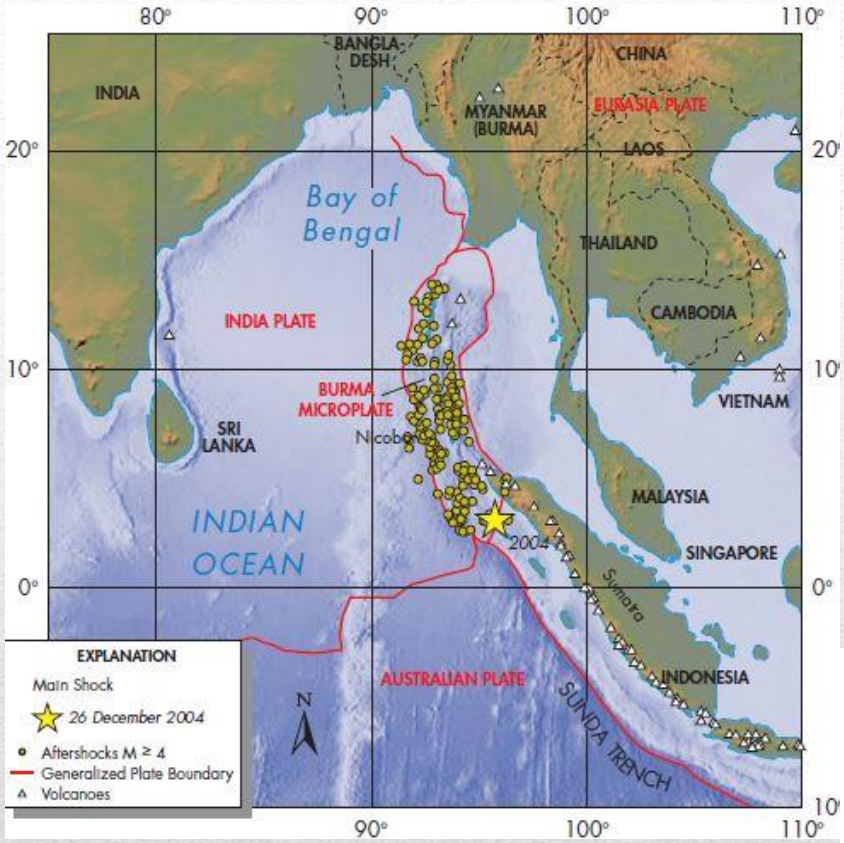
Learning Objectives

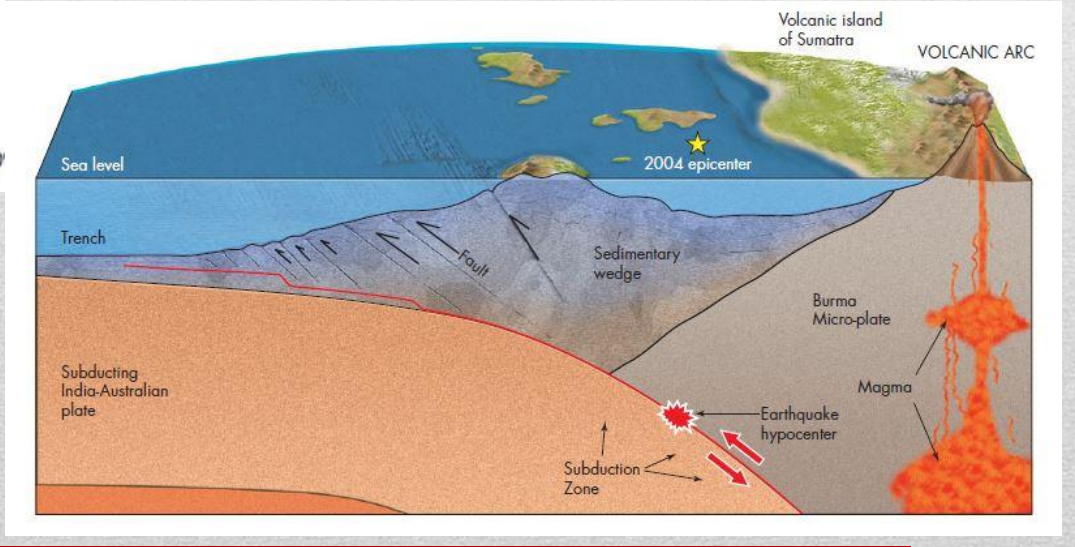
- Understand the process of tsunami formation and development
- Understand the effects of tsunamis and hazards they pose to coastal regions
- Know what geographic regions are at risk for tsunamis
- Recognize the linkages between tsunamis and other natural hazards
- Know what nations, communities, and individuals can do to minimize the tsunami hazard

Past Earthquakes and Tsunamis

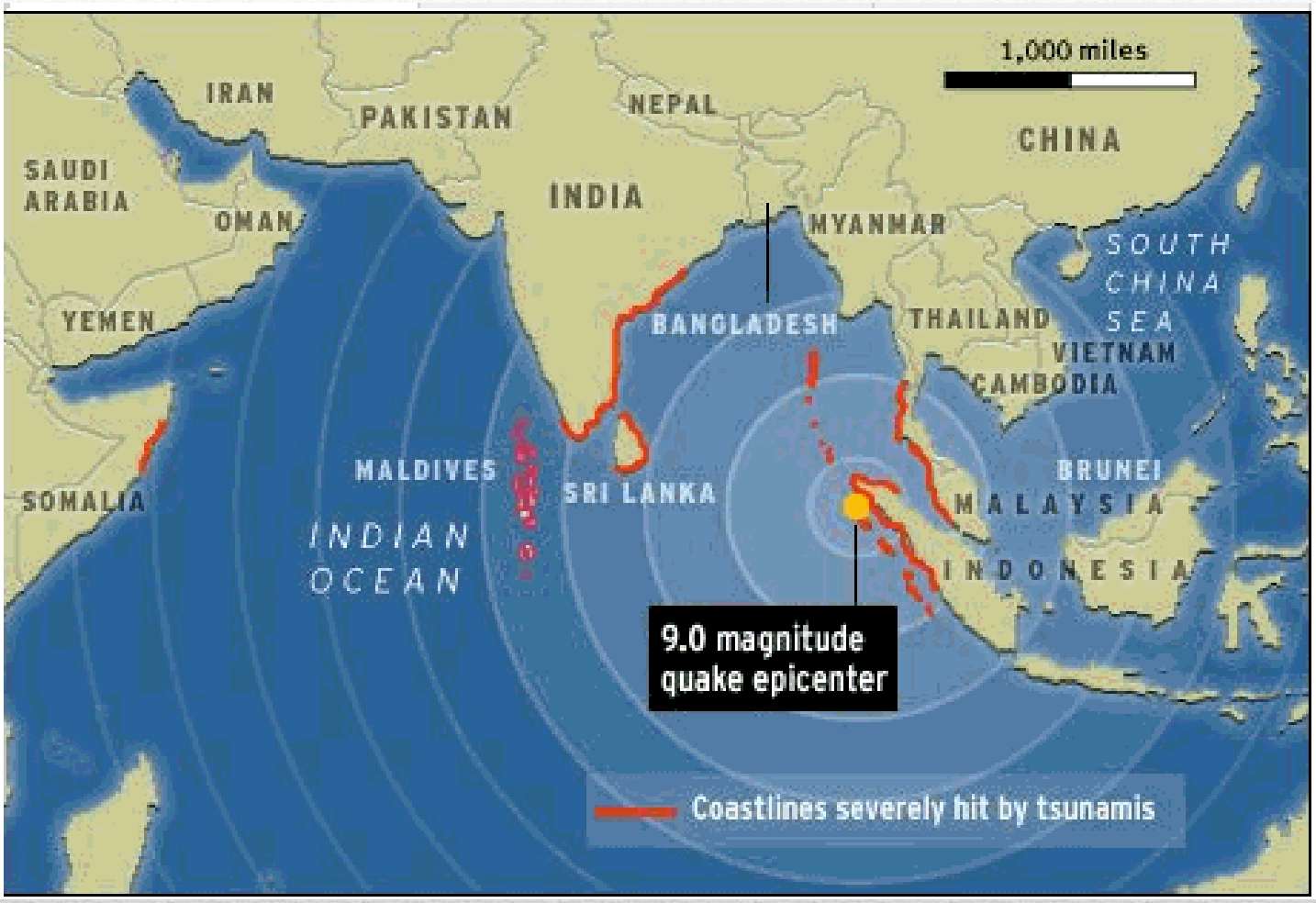
- On Dec. 26, 2004, a 9.1earthquake happened below the Indian Ocean of the west coast of Indonesia
  - The result of that earthquake was a tsunami which caused the most damage ever recorded
    - Close to 230,000 people were killed
    - Hundreds of thousands injured
    - The rupture was about the length of California and the uplift was about 65 ft.
    - There was no tsunami warning system in the Indian Ocean, leading to more people killed and hurt
    - Recognizing the signs of a coming tsunami saved many lives
- Since this earthquake and tsunami happened a warning system has been installed on the Indian Ocean floor

2004 Earthquake and Tsunami



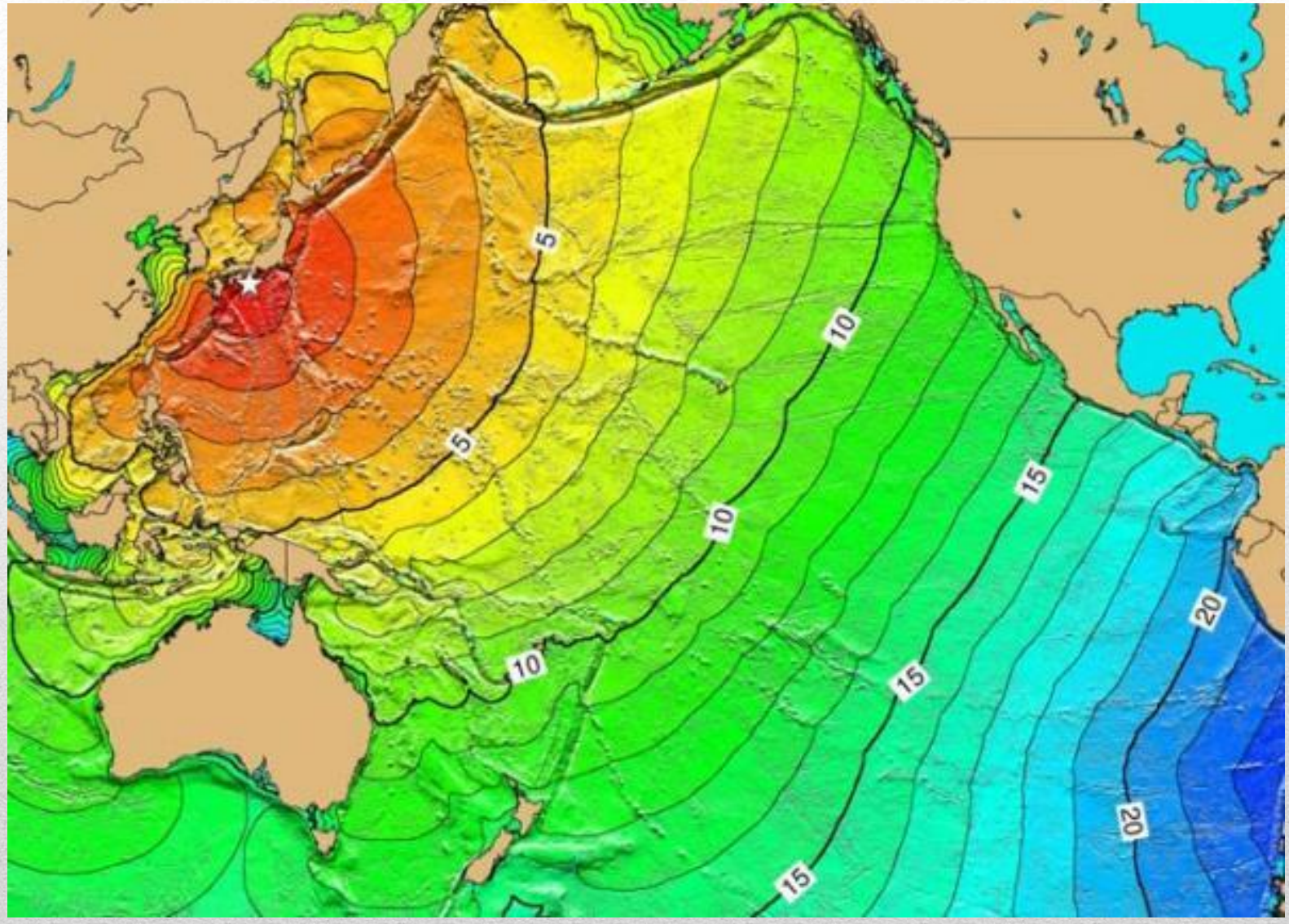


2004 Earthquake and Tsunami



2011 Japanese Earthquake and Tsunami

- 2011 a 9.0 earthquake happened with a giant tsunami to follow
  - A 6 to 8 meter upthrust happened due to the earthquake
  - This upthrust caused a tsunami that brought destruction along the Pacific Coast of Japan's northern island
  - The tsunami propagated through the Pacific Ocean to North and South America from Alaska to Chile
  - Warnings were issued and many evacuations were carried out in countries along the edge of the Pacific Ocean
  - The worse damage in Japan from the tsunami was the nuclear plant which was inundated with the waves. This cause the plant to be shut down and hoped it wouldn't have a melt down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Tsunamis

- Tsunamis – Japanese for "**large harbor waves**"
- A **serious vertical displacement of ocean water that can cause a catastrophe thousands of miles away from where they originate**
- Triggered by several types of events
  - Large earthquakes causing that causes a rapid uplift or subsidence of the seafloor
  - An underwater landslide triggered by an earthquake
  - Collapse of part of a volcano sliding into sea
  - Impact in the ocean of an extraterrestrial object such as an asteroid

How Do Earthquakes cause a Tsunami?

- **An earthquake can cause a tsunami by movement of the seafloor and by triggering a landslide**
  - Seafloor movement is the most common of these mechanisms
  - Generally it takes a M7.5 earthquake to create enough displacement of the seafloor
  - The displacement up or down begins a four-stage process that lead to landfall of tsunami waves reaching shore

How Do Earthquakes cause a Tsunami?

- **Four Stage process the leads to land fall of tsunami waves on he shore**
  1. If an **earthquake rupture uplifts the seafloor, the water surface above the uplift initially forms an elongated dome parallel to the geologic fault**
  2. In the **deep ocean, the tsunami waves move rapidly and are spaced long distances apart**
  3. As the **Tsunami wave nears land, the water depth decreases, so the velocity of the tsunami also decreases.** As the **water slows down and piles up, the height of the waves increases**
  4. When the **first wave reaches the shore and moves inland, it may be several meters to several tens of meters high**

Tsunami Waves

- Or the **trough of the wave may arrive first**
  - This will **expose the seafloor** – This behavior **fools many people who then get caught in the next incoming wave**
- Tsunami waves are not **giant breaking waves** like the surf waves
- These waves can be a **rapidly advancing surge of water up to 40 meters high**
- **Only occasionally do tsunamis break, but when they do, it is a vertical wall of turbulent water**
- The **runup** of the **wave refers to the furthest horizontal and vertical distance that the largest wave of the tsunami moves inland**

Tsunami Waves

- A Tsunami can also generate ***other types of waves called edge waves***
  - These **waves travel back and forth parallel to the shore**
  - The **interaction between edge waves and additional incoming tsunami waves can be complex**
- As a **result of this interaction, wave amplification may occur, causing the second or third wave to be even larger than the first**
- Most **commonly a series of waves will strike a particular coast over a period of several hours**

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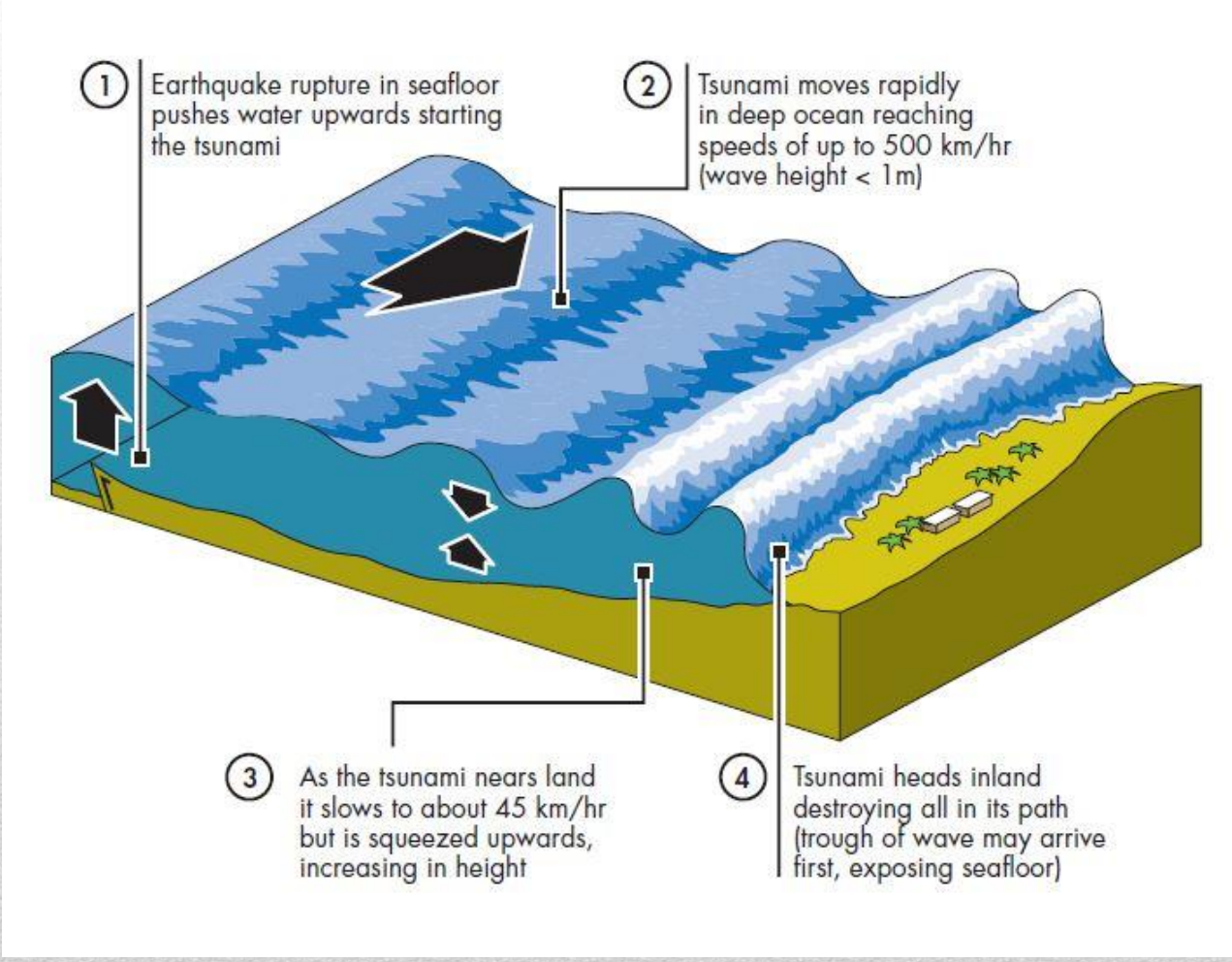
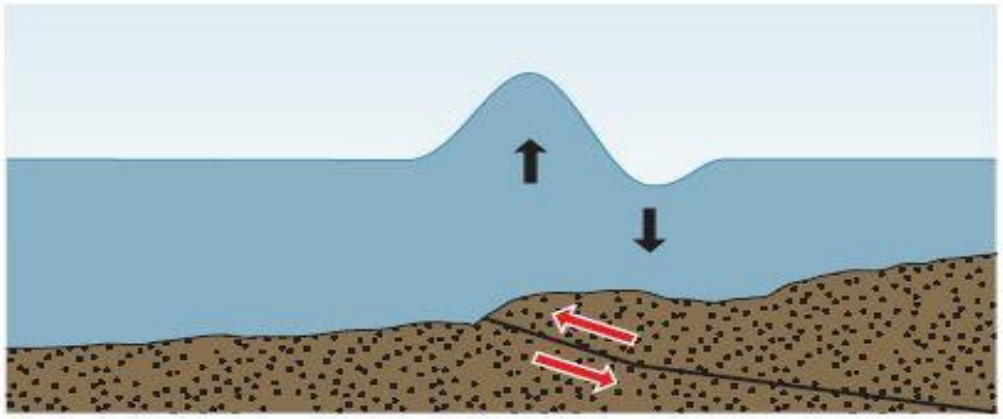
Tsunami Waves



Tsunami Waves

- As earthquakes rupture and uplifts the seafloor floor, two types of waves are produced:
  - The **Distant Wave** – the wave which moves out into the ocean
  - The **Local Wave** – the wave which moves towards the shore
- A **Distant Wave** travels thousands of miles across the ocean to strike remote shorelines
  - Allowing people on the distance shores time to move inland
  - Although there are those who **do not heed the warning**
- A **Local Wave** travel inland quickly
  - Giving coastal residents and visitors **little time to move to high land**
  - **More damage and lost of life happens**

Distant and Local Tsunami Waves



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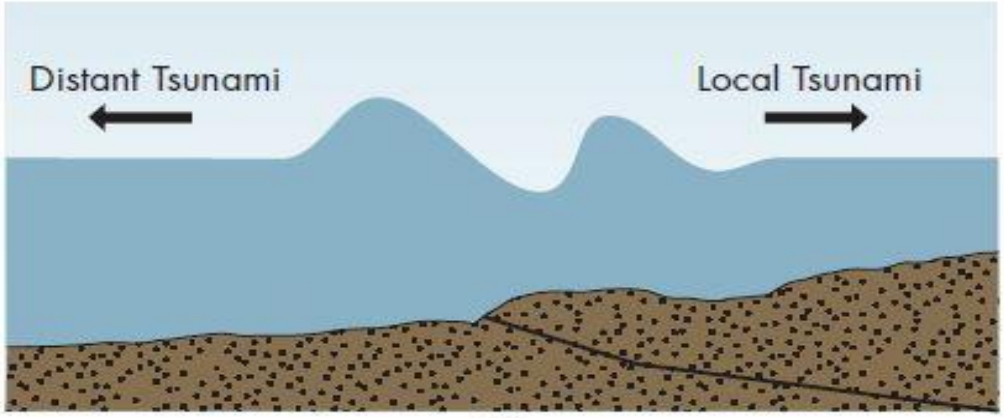

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Landslides and Tsunamis

- **How do landslides cause Tsunamis?**
  - **At times there are landslides under that ocean**
    - These landslides are called **submarine landslides**
    - Or they can be **large rock avalanches that fall from mountains into the ocean**
    - In most cases, **these landslides are caused by earthquakes**
    - The **earthquake will probably not cause a tsunami**, but the **displaced water from the landslide could cause a tsunami**

Regions at Risk of Tsunamis

- Although all ocean and some lake shorelines are at risk for tsunamis, **some are at a higher risk than others**

- **The geological location of the coast in relation to the potential tsunami sources such as earthquakes, landslides, and volcanoes causes this risk to rise**

- **Coastlines in close proximity to subduction zones are at the greatest risk for tsunamis**

Ranking the Tsunami Hazard Risk

- There is some risk for tsunamis on all ocean and some lake shorelines, but **some coasts have a high ranking because of their locations**

- The **ranking** of **tsunami hazards risks** are **based on the return period of a significant tsunami** and **how high is the runup** (how high is the wave)

- A map of global tsunamis on coastlines shows that the **highest risks are along the subduction zones of the tectonic plates**

- **Very large subduction-zone earthquakes may cause substantial damage thousands of miles from the source**

Ranking the Tsunami Hazard Risk

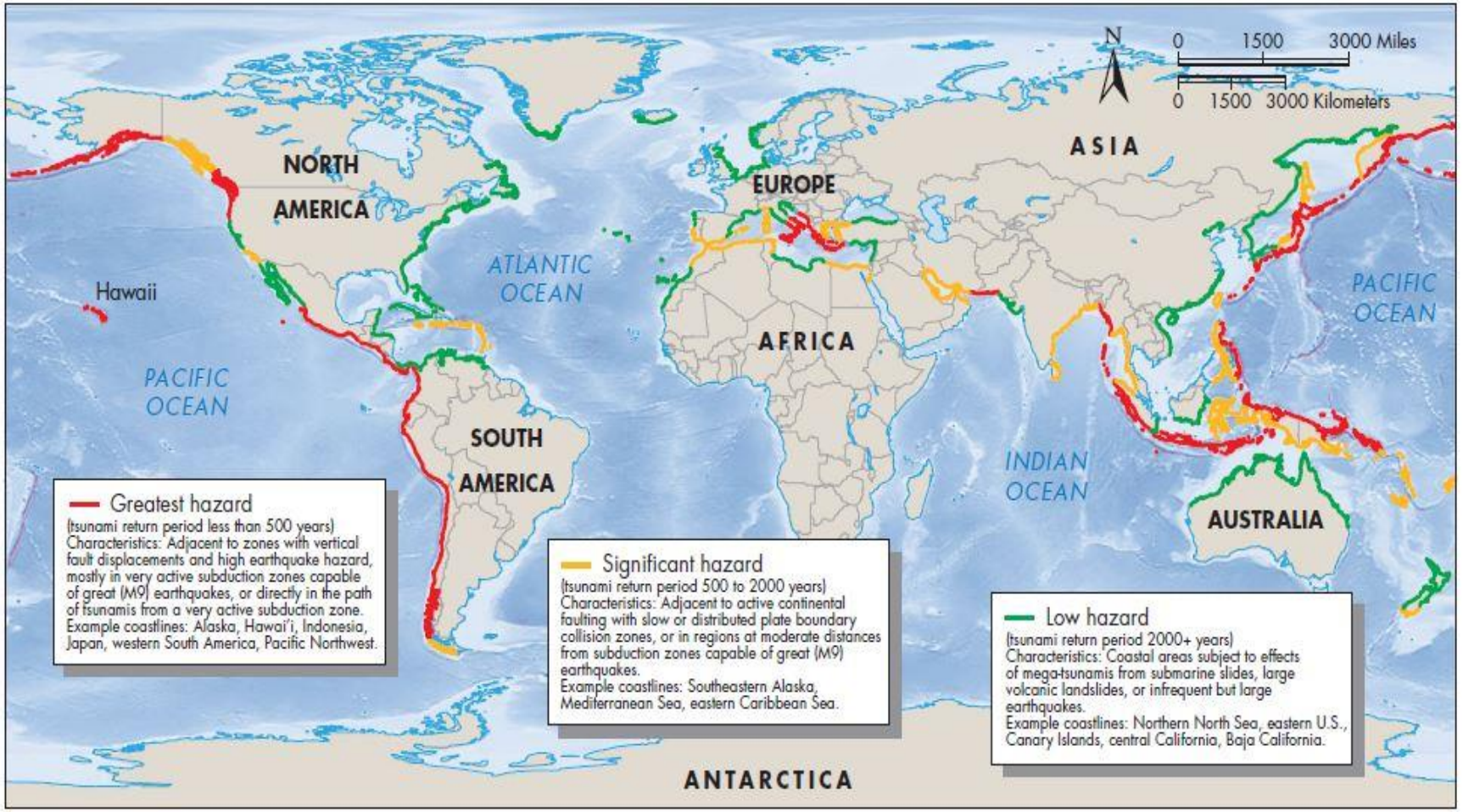
- On a map showing the **greatest, significant, and low risk areas, these subduction zones are easily seen**

- The greatest hazard zone is **around the Pacific Ocean, where there are not only tsunami hazards risks, but earthquake and volcano hazard risks also**

- The area around the **Mediterranean and around the Indian Ocean are also areas of tsunami hazard risks**

  - An example of this hazardous increase would be the **2004 Indonesian tsunami** which **killed over 200,000 people**

Ranking the Tsunami Hazard Risk



Effects of Tsunamis and Linkages with other Hazards

- Effects of tsunamis are **primary and secondary**
  - The **primary effect of a tsunami is the inundation of water and the resulting flooding and erosion**
    - The **wave energy** is sufficient to tear up beaches and coastal vegetation as well as houses and buildings
    - This **energy decreases** as it goes inland farther, leaving behind destruction in its path as it retreats

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Effects of Tsunamis and Linkages with other Hazards

- The **secondary effects of a tsunami occurs in the hours, days, and weeks after the event**

  - **Immediately after a tsunami**,
    - **Fires** may start from broken natural gas lines and electrical lines
    - **Water** supplies can be polluted from the debris and flood waters left by the tsunami
    - **Disease** may breakout due to the polluted floodwaters, damaged wastewater treatment systems, and rotting animal carcasses

Effects of Tsunamis and Linkages with other Hazards

- There are **several other linkages** with tsunamis and other hazards are:
  - **Submarine and coastal earthquakes and landslides**
  - **Island volcanic explosions**
  - **Oceanic impacts of asteroids and comets**
  - **Coastal earthquakes which cause tsunamis waves interact with the coastal processes through erosion and deposition of sediment**

Damage and Debris from 2004 Indonesian Tsunami

Natural Service of Tsunamis

- Large tsunamis are so destructive, it's hard to see any link to a service function or benefit

  - **Tsunamis bring vast amounts of seawater over the land which can leave chemicals behind which could be beneficial to some ecosystems which have been deprived of nutrients**

  - **Tsunamis also bring large amounts of sediments onshore. Over time, these sediments can fertilize the land they inundate, improving the land**

Human Interaction with Tsunamis

- **Humans cannot prevent or control tsunamis**
- **Few if any tsunamis have been effected by humans**
- **Nothing can be done to prevent to stop tsunamis**
- **But** there are **some things we can do to lessen the damage**
  - **Buffer zones can be planted along the coast to absorb some of the impact of incoming tsunami waves**
  - **Buildings can also be reinforced in areas susceptible to tsunami flooding waves**
  - **Buildings can be built further inland to avoid damage**

Minimizing the Tsunami Hazard

- A number of strategies are available **for minimizing the tsunami hazard**
  - These are some:
    - Detection and Warning
    - Structural Control
    - Construction of tsunami runup maps
    - Land Use
    - Probability analysis
    - Education
    - Tsunami-ready status

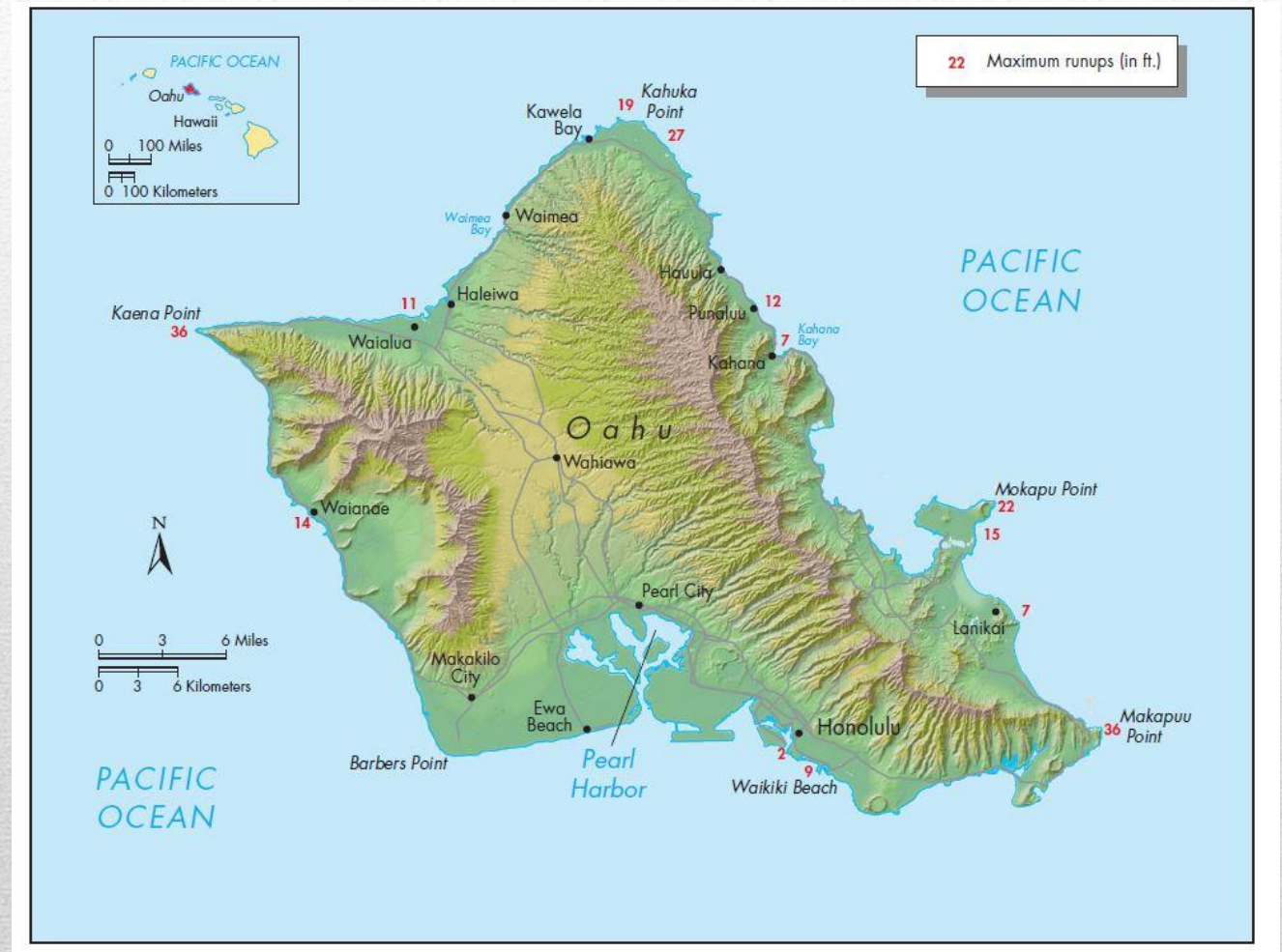
Minimizing the Tsunami Hazard

- **Detection and Warning**
  - **First warning** comes from the **detection of giant offshore earthquakes**
    - If the **tsunami forms in the open ocean, it can be detected and timed for its arrival onshore**
    - A **distant tsunami warning system has three components**
      - A **network of seismographs to locate and determine depth and magnitude**
      - **Automated tidal gauges to measure unusual rises and falls of sea level**
      - A **network of sensors connected to floating boys**
    - For **local tsunamis there may be little time for a warning system**
      - **People would feel the ground move and quick move inland**

Minimizing the Tsunami Hazard

- **Structural Control**
  - **Tsunamis even one or two meters high have the power to destroy houses or building**
    - Building designs built to withstand the destructive power of tsunamis could greatly reduce the damage caused by the waves
    - Unfortunately, the building codes are taking a long time to change to reflect this structure designs
- **Tsunami Runup Maps**
  - **After a tsunami**, it is relatively easy to produce a **tsunami runup map** showing where waves were encountered and how big they were
  - A **community in a tsunami prone area** can produce a **hazard map** showing areas where runup waves can happen
    - **These maps could help a community lesson the damage if a tsunami should happen**

Runup Map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Oahu
Hawaii
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22 Maximum runups (in ft.)
Kawela Bay
19
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Haleiwa
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Waialua
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Ewa Beach
Honolulu
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Makapuu Point
Barbers Point
Pearl Harbor
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Waikiki Beach
PACIFIC OCEAN

Minimizing the Tsunami Hazard

- **Land Use**
  - If the area has a tsunami hazard, **using specific land use helps to limit damage from the waves**
  - **Planting large trees along coastal area helps to decrease the damage behind the trees**
  - The **trees will reduce the velocity of the incoming water**
  - **Land-use planning includes**:
    - **Identifying where serious tsunami damage has or could occur can avoid damage in future tsunamis**

Minimizing the Tsunami Hazard

- **Probability Analysis**
  - The **risk of a particular even happening can be "predicted" using mathematically probability calculations**
  - **To create this probability of a tsunami happening in an area there are certain events we have to look at.** These are:
    - Identify and specify the **potential earthquake sources** and their associated uncertainties
    - Specify relationships that will **reduce the size of tsunami waves as they travel from the source area**
    - **Apply probabilistic analysis to the tsunami hazard** similar to what is **currently being done for earthquake hazard analysis**
      - **Consider that tsunamis originate from multiple sources**
        - This technique is the **Monte Carlo simulation**

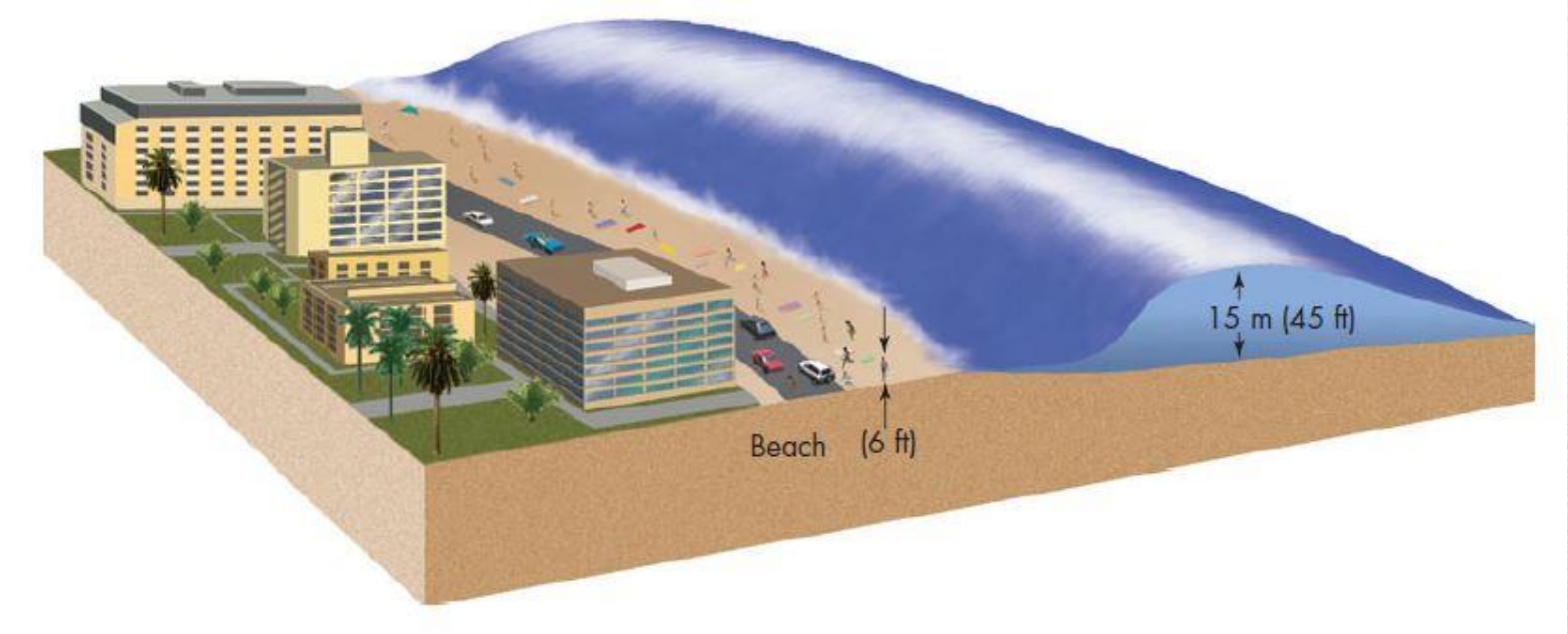
Minimizing the Tsunami Hazard

- **Education**
  - Education concerning the tsunami hazard is **critical to minimizing risk**
  - Educating people to listen for either a **tsunami watch** or a **tsunami warning is important**
  - People who know what to **look for before a tsunami wave is coming have helped to save lives during huge tsunamis**. This is **natures warning system**
  - People must learn that **tsunamis have have second and third waves**. They need to **understand that so they stay on high ground until the danger is totally gone.**

Minimizing the Tsunami Hazard

- **Tsunami-Ready Status**
  - **Establish an emergency operation center with 24- hour capability**
  - **Have ways to receive tsunami warnings: from agencies such** as: the National Weather Service, Canadian Meteorological Centre, Coast Guard, or other agencies
  - **Create other ways to alert the public**
  - **Develop a tsunami preparedness plan with emergency drills**
  - **Promote a community awareness program to educate people concerning a tsunami hazard**

Perception and Personal Adjustment to Tsunami Hazard



Perception and Personal Adjustment to Tsunami Hazard

- **Many people do not know the signs of an approaching tsunami or what to do if a watch or warning is issued**
- Personally if you are **somewhere and you find a warning is issued take the following actions:**

1. Not **all earthquakes cause tsunamis**, but they can. If **you feel an earthquake and you are on a beach area, head to high land**

2. If the **trough of a tsunami wave arrives first, the ocean will recede. This is a warning sign**

Perception and Personal Adjustment to Tsunami Hazard

3. Although **a tsunami may be relatively small at one location, it may be much larger nearby**

4. Tsunamis **generally consist of a series of waves, and there can be up to an hour between waves**

5. As **coastal communities gain tsunami-readiness status, they will have warning sirens; if you hear a siren, move away from the beach to higher ground**

6. If you are **aware that a tsunami watch or warning has been issued, do not go down to the beach to watch the tsunami**